6. Cooperative Programs

UV Spectroradiometer Monitoring Program: Calculation of Total Column Ozone from Spectra of Global Irradiance Measured at South Pole and Barrow and Comparison with CMDL/Dobson and NASA/TOMS Ozone Data

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INTRODUCTION

The U.S. National Science Foundation's Office of Polar Programs (NSF/OPP) Ultraviolet Spectroradiometer Monitoring Network was established in 1988 to collect data on the consequences of ozone depletion. The network currently consists of several sites with automated, high-resolution spectroradiometers (Table 1). Three are in Antarctica, including the CMDL site at South Pole Station. Another instrument is deployed at the CMDL facility in Barrow, Alaska. Now in its fourteenth year of operation, the network continues to make measurements of ultraviolet (UV) spectral irradiance and provides a variety of data products to quantify biologically relevant UV exposures. Biospherical Instruments Inc. is responsible for operation and maintenance of the network, and distribution of data to the scientific community.

The network is equipped with Biospherical Instruments Inc. model SUV-100 spectroradiometers. Each instrument contains a double monochromator with holographic gratings and a photomultiplier tube detector. Spectra are sampled automatically every 15 min between 280 and 600 nm with a spectral bandwidth of 1.0 nm full width at half maximum (FWHM). Tungsten-halogen and mercury vapor calibration lamps are used for daily automatic internal calibrations of both responsivity and wavelength registration. All instrument functions, calibration activities, and solar data acquisition are computer controlled. Further details on the spectroradiometers are described by *Booth et al.* [1994, 2000]. Data from the network, network operations reports, and an extensive list of references can be accessed via the website www.biospherical.com.

UV RADIATION CLIMATE AT SPO AND BRW

This report focuses on data from the South Pole Observatory (SPO) and the Barrow Observatory (BRW) CMDL facilities. The SPO site is a unique place for atmospheric studies because of the stable meteorological conditions, negligible aerosol influence, frequent cloudless days, constant and well-defined high surface albedo, and virtually constant solar zenith angle (SZA) during one day. The conditions at BRW are quite different from SPO. Cloud cover is highly variable, and significant changes in surface albedo occur due to the springtime snowmelt and changes in sea ice coverage. Also, Barrow undergoes significant changes in incident irradiance due to Arctic storms.

Figures 1 and 2 contrast the radiation patterns of both sites. Time series of integrated spectral irradiance at local solar noon are depicted for two wavelength bands covering the period 1991-2001. One spectral band (Figure 1) represents spectral irradiance in the visible, integrated between 400 and 600 nm. From Figure 1 it is evident that visible radiation at SPO shows little variation from one day to the next, or between consecutive years. In contrast, irradiances in the 400-600 nm band at BRW are highly variable during fall due to day-to-day changes in cloud cover. Because of the difference in latitude, radiation levels in the visible are usually lower at SPO than at BRW.

Figure 2 shows deoxyribonucleic acid (DNA)-weighted irradiance, which has been calculated from measured solar spectra and the action spectrum for DNA damage suggested by *Setlow* [1974]. DNA-weighted irradiance has a high contribution from wavelengths in the UVB and is therefore

TABLE 1. Installation Sites of the Ultraviolet Spectroradiometer Monitoring Network

Site	Latitude	Longitude	Established	Location
South Pole	90º00'S	-	February 1988	ARO*
McMurdo Station	77º51'S	166º40'E	March 1988	Arrival heights
Palmer Station	64º46'S	64º03'W	May 1988	T-5 building
Ushuaia, Argentina	54º49'S	68º19'W	November 1988	CADIC†
Barrow, Alaska	71º18'N	156º47'W	December 1990	UIC-NARL‡
San Diego, California	32º45'N	117º11'W	October 1992	Biospherical Instruments Inc.

*ARO, Atmospheric Research Observatory; system relocated to this new, joint NSF-CMDL facility in January 1997.
† CADIC, Centro Austral de Investigaciones Cientificas, Argentina.
‡ UIC-NARL, Ukpeagvik Inupiat Corporation-Naval Arctic Research Laboratory.

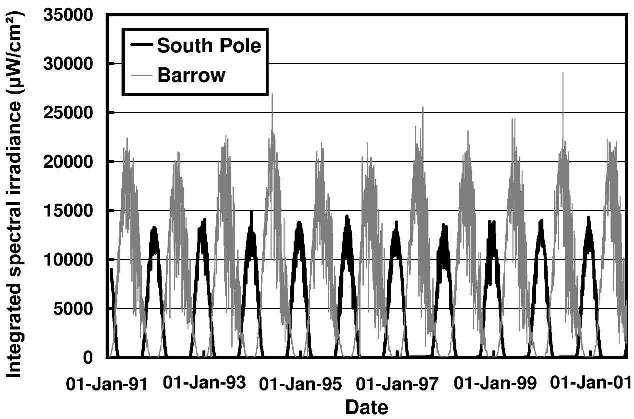

Fig. 1. Visible spectral irradiance (400-600 nm integral) at local solar noon at South Pole and Barrow for the period 1991-2001.

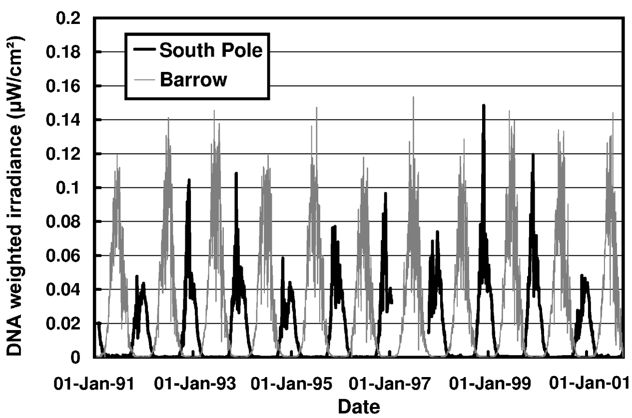

Fig. 2. DNA-weighted irradiance at local solar noon at South Pole and Barrow for the period 1991-2001.

very sensitive to changes in atmospheric ozone concentrations. In contrast to visible radiation, DNA-weighted irradiance at SPO shows high day-to-day fluctuations because of the ozone influence. For example, the peak in DNA-weighted irradiance observed at SPO in late November 1998 is due to extraordinarily low total column ozone values and the comparatively high solar elevations prevailing during this part of the year. UV levels in the austral spring of 2000 were affected by the unusual behavior of the ozone hole of that year, which was exceptionally large until early October 2000 before it exhibited an unprecedented rate of decrease in size and depth. Between mid-October and mid-December 2000, levels of DNA-weighted irradiance at SPO were low compared with typical values from other years.

Calculation of Total Column Ozone from Spectra of Global Irradiance

A new method was developed in 2001 to retrieve total column ozone from measurements of spectral global irradiance of the SUV-100 network instruments. In brief, the method is based on the comparison of measured spectra with results of the radiative transfer model UVSPEC/libRadtran, available at www.libradtran.org. For every measured spectrum, several model runs with different values of the model input parameter "ozone column" are performed. The ozone value retrieved by the method is the model ozone value that gives the best agreement between measurement and model. More details on the algorithm are given by *Bernhard et al*. [2002].

The assessment of the method revealed that its accuracy is affected by the atmospheric ozone profile when SZAs are larger than 75°. This fact is particularly important for SPO and BRW, where large SZAs are prevailing. Ozone values were therefore retrieved both with standard profiles and profiles measured by CMDL with balloon ozonesondes [*Bernhard et al.,* 2002].

Comparison of Ozone Values

Values of total column ozone retrieved from the SUV-100 measurements with the algorithm introduced above were compared with Dobson ozone measurements performed by CMDL at SPO and BRW, and with satellite ozone observations by the National Aeronautics and Space Administration (NASA) Earth Probe Total Ozone Mapping Spectrometer (TOMS). Figure 3 shows the ratios of ozone values from the SUV-100 and TOMS to the Dobson values at SPO for the period October-December 2000, referenced to the CMDL Dobson measurements. SUV-100 ozone values were determined with CMDL balloonsonde ozone and temperature profiles in the retrieval algorithm. Figure 3 shows that SUV-100 and Dobson measurements agree to within ±1.5% for SZAs as high as 80°. TOMS observations are generally 5-10% higher than Dobson ozone

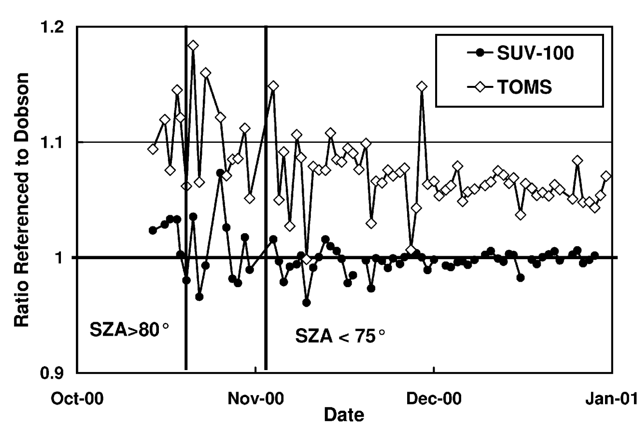

Fig. 3. Comparison of SUV-100 and TOMS total column ozone measurements at South Pole with CMDL Dobson ozone observations during austral spring 2000.

measurements. This deviation of TOMS and ground-based ozone observations at high latitudes of the southern hemisphere has been noticed before [e.g., *Piacentini et al.*, 2000]. Because SUV-100 measurements represent an independent data set, they can be used to validate ozone measurements from other instruments, elucidating the observed discrepancies.

SUV-100 ozone values at BRW were calculated for March-April 2001 during the period of the Total Ozone Measurements by Satellites, Sondes, and Spectrometers at Fairbanks ($TOMS^3F$) campaign. Preliminary results show that Dobson observations during April 2001 were on average 2% lower than SUV-100 measurements; TOMS and SUV-100 data agreed to within ±0.5%. Despite the good agreement, uncertainties in the SUV-100 data are larger at BRW than at SPO, because no ozone and temperature profile observations are available from Barrow. Profiles were therefore taken from CMDL balloonsonde flights at Fairbanks. Because Barrow and Fairbanks are separated by more than 6° latitude, the definition of the profile is less accurate than it is for South Pole. As of this writing, the data are still under evaluation. One further objective is to quantify the recently observed drift of TOMS ozone data due to deterioration of the instrument's scan mirror, by comparing different versions of TOMS data with SUV-100 ozone retrievals.

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